First Evaluation Results of the Water Indication Mask as a By-product of the TanDEM-X DEM

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Abstract

The main goal of the TanDEM-X mission is the production of a global Digital Elevation Model (DEM). A by-product is the so-called Water Indication Mask (WAM). The purpose of this supplementary information layer is to support the DEM editing process where the DEM is noisy**.** The WAM is derived from the SAR amplitude and the single-pass coherence. In this paper, the methodology of the water body detection is briefly explained and the results of four test sites covering different climatic regions are evaluated. The different characteristics of the WAM using amplitude and coherence image are described and their respective pros and cons are discussed.

1 Introduction

Water surfaces usually show lower coherence in an interferometric data set due to temporal de-correlation and low backscattering. Consequently, the corresponding elevation values derived from the interferogram are random and produce a virtual relief. The goal of the Water Indication Mask (WAM) is to detect the disturbed surface of water bodies that will remain in the final DEM layer and hence to support a subsequent DEM editing as flattening of rough surfaces.
The WAM is produced in the 'DEM Mosaicking and Calibration Processor' (MCP). The MCP is responsible for providing a consistent global DEM product [1] and is the subsequent processor to the 'Integrated TanDEM-X Processor' [2]. The DEM preparation process analyses every single DEM scene individually. The goal of this process is to provide a complete input for the later on DEM calibration and mosaicking up to the resulting final DEM product [3] [4].
The water body detection bases on a threshold method applied on the SAR amplitude and the single-pass coherence. Due to different characteristics and appearance of water bodies in amplitude and coherence data, the thresholding results differ. The methodology of the water body detection and fusion into the WAM product is described briefly in Section 2. With the help of four different test sites (Section 3), the characteristics of the WAM depending on land cover and terrain type are detailed and their respective advantages and disadvantages are discussed (Section 4). The results are evaluated visual. The focus here is a first step of an analysis when to use the amplitude derived WAM and/or the coherence derived WAM.

2 Methodology of Water Body Detection

The water body detection contains two main steps. The first step is the creation of the Water Body Detection Mask (WBD) on the basis of a threshold method and a subsequent morphology cleaning step using amplitude and coherence image. Therefore, two amplitude – a stronger and a weaker value - and one coherence threshold value are used. It is derived from every single DEM scene. More information about the algorithm can be found in [5]. The second step is the fusion of all WBD of the first and the second acquisition to the final product, the Water Indication Mask. The naming already suggests that this final mask gives just an *indication* for water but no water inventory mask. The indication for water is given by the sum of the counts of the individual classifications for each pixel. The more counts the more secure the detection of water - within the specific scene. The resulting WAM provides the counts separately for each threshold - two amplitude thresholds and one coherence threshold. A maximum number of three counts is possible for each threshold as this corresponds to the maximum findings: one in each of the two coverages and one in an additional coverage in difficult terrain or alternatively one in the 4 km overlap in range of neighbouring acquisitions. A combination in this way corresponds to a fusion by union. [6] represents the method more specific.

3 Test Sites

The first test site is located along Mozambique's tropical shore near Quelimane city. Beside the shallow bulwark water bodies are classified within a winding mangrove river delta. The second test site is located in central of Kenya near the equator. With its dry landscape it represents the semi-arid area. As an example for coastal regions an area in southern Denmark at the Belt of Fehmarn is examined. Shelves and little tidal influence cause disturbed and rough water surfaces. The fourth test site covers inland water detection under the action of frost in the middle of Minnesota, USA. The data are acquired in winter, all lakes are frozen. Since 87 % of the TanDEM-X acquisitions in the northern hemisphere above 60° latitude are acquired in winter this happens in those areas quite often.

4 Visual Evaluation of WAM result

Depending on land cover and terrain type water bodies show different characteristics and appearance in the amplitude and the coherence data. Hence, the threshold results differ. Therefore, an evaluation of the WAM is an important step. The comparison between the amplitude and the coherence derived WAM is performed visually for the test sites.

4.1 Tropics and mid-latitudes

The mangrove river delta in Mozambique (Fig. 1) represents the test site in tropic areas. The water bodies appear smooth and dark without any disturbances caused by wind or other effects. All inland lakes are accurate detected with the threshold method on the amplitude and the coherence image. For the DEM editing the information of the coherence image is valuable as incoherent areas indicate where the DEM is noisy and needs to be filtered or flattened. Hence, the depiction of the WAM in figure 2 indicates primarily the water areas which are identified in the coherence image. Theses areas are delineated in blue. All water areas which are additionally derived with the weaker amplitude threshold are displayed in orange, classifications of the stronger amplitude threshold in green. In contrast to the coherence, the amplitude threshold show also finger details of water bodies, since coherence was processed with a very huge filter. The central part of the figure is delineated in a darker blue. The darker the colour, the oftener the pixel is classified as water. In this case the pixel is classified twice as water due to the overlapping of two acquisitions. With this depiction the additional benefit of the amplitude threshold is distinguishable. Parts of the river in the lower right of the figure and a lot of details like feeder and small rivers are only displayed in orange and green, thus they are only derived from the amplitude image. In contrast, the disadvantages are the misclassification of agriculture areas with the weaker ampli tude threshold, which can be seen in the upper right part in figure 2. Hence, the classifications of the coherence-derived WAM are more reliable. The combination of amplitude and coherence derived WAM would complement the information especially with regard to DEM editing. Equally in the mid-latitudes, the combination of both information layers leads to an additional benefit. It must keep in mind that in mid-latitudes and tropical areas forest show also a low coherence and that it is susceptible for misclassifications. Comparisons of the individual threshold results can be found in [5, 6].

Figure 1: Amplitude image of Mozambique

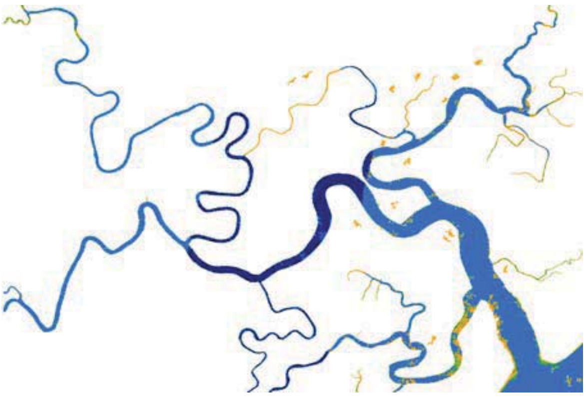

Figure 2: WAM of Mozambique

4.2 Semi-arid areas

Semi-arid areas like in Kenya appear often dark in the SAR amplitude image. The stronger amplitude threshold leads to misclassifications of semi-arid areas. However, the weaker amplitude threshold and the coherence threshold detect the water bodies reliable with almost no misclassification. In this case the weaker amplitude threshold delivers valuable information. A combination of the coherence threshold value and the weaker amplitude threshold would complement well the information layer for the DEM editing.

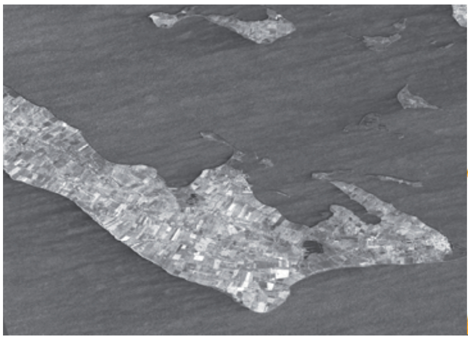

Figure 3: Amplitude mosaic (mean value) of southern Denmark

Figure 4: WAM derived with the weaker amplitude threshold (orange)

Figure 5: WAM derived with the coherence threshold (blue)

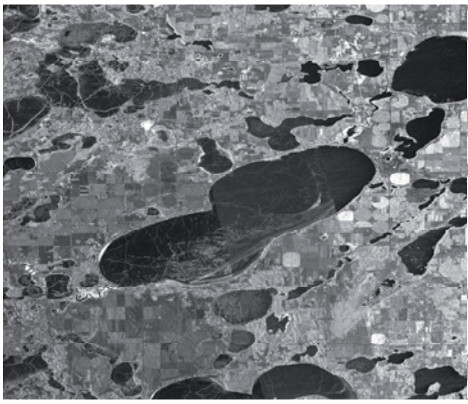

Figure 6: Amplitude mosaic (mean value) of Minnesota acquired on 07.12.2010 (left scene) and 24.10.2010 (right scene)

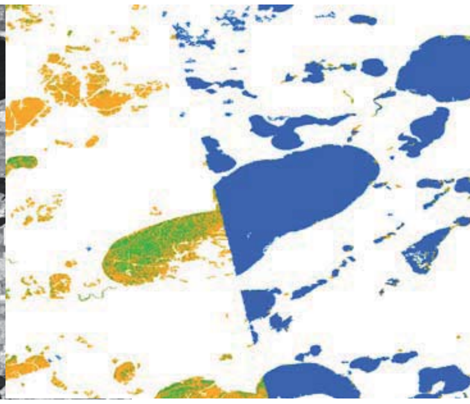

Figure 7: WAM derived the strong amplitude threshold (green), with the weaker amplitude threshold (orange) and the coherence threshold (blue)

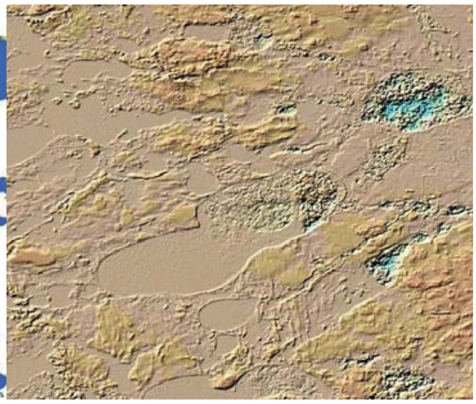

Figure 8: TanDEM-X DEM mosaic (not edited) of Minnesota

4.3 Coastal region

In most cases inland water appears black in the amplitude image, i.e. it is easy to detect. In contrast, the amplitude image of the ocean in southern Denmark in figure 3 shows that the influence of wind leads to the origination of ripples and waves on water surfaces and hence the water appears rough. Large water areas in coastal regions are more susceptible to wind than small lakes in the inland. Figure 4 shows the water areas derived from the amplitude image. It is obvious that the amplitude thresholding is limited. In contrast the coherence derived WAM in figure 5 classifies the ocean reliable and correctly. In this case the coherence derived WAM is an important information layer for the classification of rough water surfaces and for the delineation of coastlines. The amplitude derived WAM has no additional benefit.

4.4 Frozen water bodies

Figure 6 shows the mosaicked amplitude of two different acquisitions of Minnesota. The right part presents the amplitude acquired during summer time. As explained in section 4.1, inland lakes in mid-latitudes are detected with the amplitude and the coherence threshold very well. The left part presents the amplitude acquired during winter. In this case all water areas are frozen. Frozen areas induce a high coherence; hence, the water areas can not be detected with the coherence thresholding. Also the amplitude thresholding is limited. The WAM of this test site is displayed in figure 7 and bases on the same labelling as figure 2. The right part of the lake detected with the amplitude and the coherence thresholding. Since the information of the coherence image is valuable for the DEM editing, the figure shows only the classification results of the coherence (blue). The left part is only detected with the amplitude thresholding which is recognisable on the green and orange colour. The backscattering of the SAR signal depends on the smoothness of the ice: the smoother the ice, the darker the water areas are. The results of the amplitude derived WAM are not very reliable. The lower part of the frozen lake for example is too bright and can not be detected as water. Figure 8 shows the DEM of Minnesota which is not edited. It is obvious that due to the high coherence, the DEM is already flat and needs no editing afterwards In this case both classification results can be neglected for the winter part. For the summer part, the combination of amplitude and coherence derived WAM would complement the information layer (Section 4.1).

5 Conclusion

The WAM bases on a threshold method applied on the SAR amplitude and the single pass coherence. In general, a combination of the amplitude and the coherence derived WAM helps to compensate missing classification results due to temporal changes, coherent water or missing SAR backscattering. The WAM do not present a complete water mask. But with a precise combination of the classification results it can be used for a helpful indication of water bodies. Due to its global coverage, the WAM will be an outstanding information layer. On a case by case basis first recommendations are worked out which information out of the WAM is best to use

In tropics and mid-latitudes the combination of both thresholding leads to a complete information layer for e.g. DEM editing. The weaker amplitude threshold is prone to misclassification of agriculture areas as water. On the other hand its benefit is to complete the information layer with the classification of small rivers and thin water areas. In mid-latitudes and tropics forest show also a low coherence which can lead to misclassifications in the coherence-derive WAM. Since semi-arid areas appear dark in the SAR amplitude image, the combination of the weaker amplitude and the coherence threshold is advised. For the classification of coastal regions the coherence-derived WAM is a reliable information layer. Due to the rough water surfaces induced by wind and wave the amplitude-derived WAM can not be used as information layer. Since frozen water areas covered with ice induce a high coherence, the DEM is already flat and needs no editing.

References

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